

APPENDIX: OPERATIONAL PROCEDURES
40 CFR 146.82(a)(10)

Facility Information

Facility Name: CTV II

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Well locations:

[REDACTED]
[REDACTED]

7.1 Operational Procedures [40 CFR 146.82(a)(10)]

Injectors will be operated to inject the desired target rate of CO₂ over their operating period. Operating procedures for the two planned injectors in the project are described below.

7.1.1 Injector [REDACTED] Operating Procedures

For a target rate of [REDACTED] million standard cubic feet per day (mmscf/d), bottom hole and surface pressures have been estimated for the well over the life of the project. These pressures were estimated using results from the reservoir simulation as an input into the multiphase well nodal analysis software – PROSPER by Petroleum Experts Ltd. PROSPER has been used extensively in CO₂ EOR to model CO₂ injection wells. The pressures have been currently calculated assuming a 100% CO₂ stream. Operating conditions will be updated as CTV defines the injection stream and impurities.

At the start of injection, surface and bottom hole injection pressures of 945 psi and 1,533 psi respectively, are required to inject the target rate. As the pressure in the reservoir builds up, increasing surface and bottom hole pressures will be required to maintain injection at the target rate. At the end of injection, the estimated surface and bottom hole pressures required are 1,425 psi and 4,711 psi, respectively.

The expected fracture pressure gradient for the injection zone is estimated to be 0.7 – 0.8 psi/ft, and 0.70 psi/ft is conservatively used for the wellbore performance modelling. Using a 10% safety factor, as per the EPA's guidelines, the maximum allowable BHP is 6,021 psi (calculated at the top perforation TVD). Prior to injection, during pre-operational testing, the reservoir fracture gradient will be determined with step-rate testing to confirm maximum allowable injection pressure. During injection, the well will be controlled using automation to never exceed the maximum allowable bottomhole injection pressure. The estimated bottom hole pressures over the life of the project are lower than the maximum allowable bottom hole pressure of 6,021 psi.

The expected beginning and ending pressures for injector [REDACTED] are summarized in Table 7.1.

Table 7.1: Proposed operational conditions

Parameters/Conditions	Limit or Permitted Value	Unit
Maximum Allowable Pressure	Using 0.70 psi/ft frac gradient with 10% safety factor	
Surface	2,529	psig
Downhole	6,021	psig
Injection Pressure @ Target Rate	Expected range over project	
Surface – Start / End	945 / 1,425	psig
Downhole – Start / End	1,533 / 4,711	psig
Target Injection Rate	■	mmscf/d
Average Injection Volume and/or Mass	■ million	tons
Annulus Pressure @ Target Rate	Expected range over project	
Surface – Start / End	100 / 632	psig
Downhole – Start / End	4,279 / 4,811	psig
Target Annulus / Tubing Pressure Differential	>100	psig

7.1.1.1 Annulus Pressure

Annular pressure between the tubing and production casing above the packer will be maintained to achieve the requirements of 40 CFR 146.88 (c).

The minimum applied annular surface pressure will be maintained at or greater than 100 psi during injection. This ensures a low-pressure alarm can be used to indicate loss of annular pressure as a potential well integrity concern. Surface pressure will be monitored continuously and evaluated according to Attachment C: Testing and Monitoring Plan.

CTV will maintain downhole annular pressure at the packer greater than 100 psi above injection pressure for all bottomhole injection pressures. This pressure differential is achieved by the combination of hydrostatic pressure from annular packer fluid and surface applied annular pressure. As bottomhole pressure increases throughout the injection phase of the project, annular pressure will be increased to ensure the target differential pressure between the tubing and tubing annulus is maintained at greater than 100 psi.

CTV intends to use 4% KCl completion fluid with corrosion inhibition and biocide as packer fluid. 4% KCl is compatible with all well components and is not corrosive. The specific gravity of the packer fluid is estimated to be 1.024.

The range of annular pressures described in Table 7.1 are suitable to the well design and will not impact the well integrity or induce formation fracture.

7.1.1.2 Target Injection Rate

Surface wellhead and downhole conditions will be monitored continuously. Injection rate or mass flow is one of the parameters to be monitored at surface. Thresholds will be established based on limitations of well equipment and geological concerns downhole with respect to the target injection rate.

At this time, for injection well [REDACTED], CTV expects a target injection rate of [REDACTED] million cubic feet per day for which the maximum expected bottom hole injection pressure is 4,711 psi. A threshold of 10% over the target values will be used to configure automation and alarms, which equates to [REDACTED] million cubic feet per day and 5,182 psi. If either threshold is achieved or exceeded, the system will deliver alarms to indicate there is an issue. Resolution will depend on the type of alarm and systems installed to regulate the injection rate. Typically, this will require a reduction in the injection rate without the need for a shutdown. However, the situation will be reviewed to understand what systems failed or did not perform properly and thus created an excessive injection rate.

7.1.1.3 Shutdown Procedures

Under planned, routine shut down events (e.g., for well workovers), CTV will reduce CO₂ injection at a rate of ~[REDACTED] mmscf/d over a 6-day period to ensure protection of health, safety, and the environment.

7.1.1.4 Automated Shutdown System

Downhole temperature and pressure along with surface flow or mass movement, surface pressure, and temperatures will be monitored in real time. Data will be collected in an automated system and monitored by a control system with established operating thresholds. After a threshold is observed or exceeded, the software will issue visual, audible, and digital alerts and/or begin with an unload procedure and transition into the shutdown process for appropriate equipment until it is understood why the thresholds were achieved and whether corrective measures must be implemented.

CTV has not established the monitoring system at this time. Upon establishing the system and thresholds CTV will communicate with the EPA.

7.1.2 Injector [REDACTED] Operating Procedures

For a target rate of [REDACTED] million standard cubic feet per day (mmscf/d), bottom hole and surface pressures have been estimated for the well over the life of the project. These pressures were estimated using results from the plume simulation as an input into the multiphase well nodal analysis software – PROSPER by Petroleum Experts Ltd. PROSPER has been used extensively in CO₂ EOR to model CO₂ injection wells. The pressures have been currently calculated assuming a 100% CO₂ stream. Operating conditions will be updated as CTV defines the injection stream and impurities.

At the start of injection, a surface and bottom hole injection pressure of 928 psi and 1,478 psi respectively, are required to inject. As the pressure in the reservoir builds up, higher surface and bottom hole pressures will be required. At the end of injection, the estimated surface and bottom hole pressures required are 1,393 psi and 4,672 psi respectively. The estimated bottom hole pressure is lower than the maximum allowable bottom hole pressure of 6,061 psi.

The expected fracture pressure gradient for the injection zone is estimated to be 0.7 – 0.8 psi/ft, and 0.70 psi/ft is conservatively used for the wellbore performance modelling. Using a 10% safety factor, as per the EPA's guidelines, the maximum allowable BHP is 6,061 psi (calculated at the top perforation TVD). No directional survey is available for this well, so well measured depth is assumed equal to true vertical depth. A directional survey will be acquired during pre-operational testing, and calculations will be updated. Prior to injection, during pre-operational testing, the reservoir fracture gradient will be determined with step-rate testing to confirm maximum allowable injection pressure. During injection, the well will be controlled using automation to never exceed the maximum allowable bottomhole injection pressure. The expected pressures for injector [REDACTED] over the life of the project are summarized in Table 7.2.

Table 7.2: Proposed operational conditions

Parameters/Conditions	Limit or Permitted Value	Unit
Maximum Allowable Pressure	Using 0.70 psi/ft frac gradient with 10% safety factor	
Surface	2,573	psig
Downhole	6,061	psig
Injection Pressure @ Target Rate	Expected range over project	
Surface – Start / End	928 / 1,393	psig
Downhole – Start / End	1,478 / 4,672	psig
Target Injection Rate	[REDACTED]	mmscf/d
Average Injection Volume and/or Mass	[REDACTED] million	tons
Annulus Pressure	Expected range over project	
Surface – Start / End	100 / 542	psig
Downhole – Start / End	4,330 / 4,772	psig
Target Annulus / Injection Tubing Pressure Differential	>100	psig

7.1.2.1 Annulus Pressure

Annular pressure between the tubing and production casing above the packer will be maintained to achieve the requirements of 40 CFR 146.88 (c).

The minimum applied annular surface pressure will be maintained at or greater than 100 psi during injection. This ensures a low-pressure alarm can be used to indicate loss of annular pressure as a potential well integrity concern. Surface pressure will be monitored continuously and evaluated according to Attachment C: Testing and Monitoring Plan.

CTV will maintain downhole annular pressure at the packer greater than 100 psi above injection pressure for all bottomhole injection pressures. This pressure differential is achieved by the combination of

hydrostatic pressure from annular packer fluid and surface applied annular pressure. As bottomhole pressure increases throughout the injection phase of the project, annular pressure will be increased to ensure the target differential pressure between the tubing and tubing annulus is maintained at greater than 100 psi.

CTV intends to use 4% KCl completion fluid with corrosion inhibition and biocide as packer fluid. 4% KCl is compatible with all well components and is not corrosive. The specific gravity of the packer fluid is estimated to be 1.024.

The range of annular pressures described in Table 7.2 are suitable to the well design and will not impact the well integrity or induce formation fracture.

7.1.2.2 Target Injection Rate

Surface wellhead and downhole conditions will be monitored continuously. Injection rate or mass flow is one of the parameters to be monitored at surface. Thresholds will be established based on limitations of well equipment and geological concerns downhole with respect to the target injection rate.

At this time, for injection well [REDACTED], CTV expects a target injection rate of [REDACTED] million cubic feet per day for which the maximum expected bottom hole injection pressure is 4,672 psi. A threshold of 10% over the target values will be used to configure automation and alarms, which equates to [REDACTED] million cubic feet per day and 5,139 psi. If either threshold is achieved or exceeded, the system will deliver alarms to indicate there is an issue. Resolution will depend on the type of alarm and systems installed to regulate the injection rate. Typically, this will require a reduction in the injection rate without the need for a shutdown. However, the situation will be reviewed to understand what systems failed or did not perform properly and thus created an excessive injection rate.

7.1.2.3 Shutdown Procedures

Under planned, routine shut down situations (e.g., for well workovers), CTV will reduce CO₂ injection at a rate of ~[REDACTED] mmscf/d over a 6-day period to ensure protection of health, safety, and the environment.

7.1.2.4 Automated Shutdown System

Downhole temperature and pressure along with surface flow or mass movement, surface pressure, and temperatures will be monitored in real time. Data will be collected in an automated system and monitored by a control system with established operating thresholds. After a threshold is seen or exceeded, the software will issue visual, audible, and digital alerts and/or begin with an unload procedure and transition into the shutdown process for appropriate equipment until it is understood why the thresholds were achieved and what corrective measures must be implemented.

CTV has not established the monitoring system at this time. Upon establishing the system and thresholds CTV will communicate with the EPA.